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Price of 2G HTS Wire: Plenty of Room to Go Down

Vladimir Matias (iBeam Materials, Santa Fe, NM 87507 USA) vlado@ibeammaterials.com
Brian Moeckly (Common Fusion Systems, Milpitas, CA, USA) brian@cfs.energy

The price and availability of high temperature superconductor (HTS) wire are critical for enabling commercialization of the many applications utilizing such wire. Unfortunately, the high price of existing HTS wire represents a large fraction of the cost of goods for nearly any proposed superconducting technology, thereby hampering broad deployment. This is equally true for superconducting magnets used in high energy physics (HEP) applications. Thus it remains critically important to understand the economics of HTS wire production. The existing price of HTS wire is high not only because there is no substantial commercial market for the wire, but also because the manufacturing techniques presently employed are not easily scalable to high volumes nor low cost. We believe that with the advent of scalable production methodologies the wire cost can be reduced by 20× and production volumes can be increased by 50× with capital investments similar to those that have been made to date. This breakthrough can now be more readily achieved due to emergence for the first time of an application that requires high volumes of HTS wire to achieve its aims: the tokamak fusion machines being designed by Commonwealth Fusion Systems [1].

Figure 1 displays the price over time of so-called 2nd generation (2G) HTS wire (or tape), also known as coated conductor. Its price is commonly quoted in \$/kA•m at 77 K and self-field. The figure shows the price and worldwide production volume for 2G HTS wire during the first 15 years of its availability. The price initially dropped dramatically from very high values before long-length manufacturing was implemented and production yields improved. After production was scaled to longer lengths the prices settled and saturated, though unfortunately there was no market demand to further drive scaling of production volumes. The graph also shows the cost of embodied materials, at current performance levels, and the practical absolute lower limit on materials costs from a deposition process.

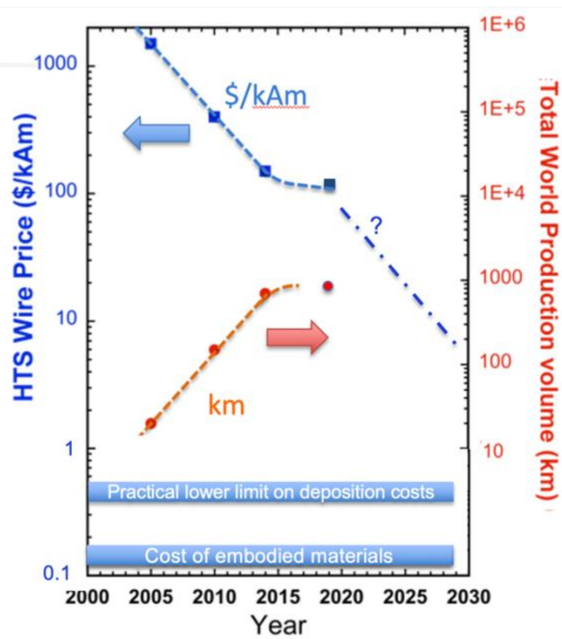

Fig. 1 Price of 2G HTS wire and production volume over time. At the bottom are the cost of embodied materials and lower limit on materials deposition costs. The dotdash line is proposed by the authors to be feasible with scale up of wire manufacturing.

Matias and Hammond [2,3] presented an analysis of 2G wire showing that cost could be as low \$2/kA•m, at least for co-evaporation deposition methods. Critically, these analyses showed that scaling up to larger substrate widths is important for cost reduction. However, not all current production approaches are amenable to wide web production. We believe the next significant step in reduction of manufacturing costs will be driven by scaling up production to wider webs and that this step is by far the most important driver for cost reduction of HTS wire. Deposition methods that are more easily scalable will therefore have a significant advantage in this regard.

Concomitant with vastly reducing production costs, scaling to wider width fabrication also enables enormous increases in production capacities for similar capital outlays. Based on the trends indicated in Figure 1, existing production methodologies which produce HTS films on 12-mm-wide substrates would require a 1000× increase in production volume to achieve the required low cost, i.e., from a present production volume of ~1000 km/year (of 4-mm-wide HTS wire) to roughly 1M km/year. In our view this demand is not realistic, so in order to reduce the price of HTS wire to a few $/kA•m, a revolution in production methodology is required, which we believe is possible.

While existing HTS wire suppliers typically produce and sell a couple hundred km of wire per year, a single commercial fusion machine as envisioned by CFS would require ~20,000 km of wire, and future energy needs will require thousands of these machines. Hence, we are on the cusp of a breakthrough in a technology pull for HTS wire, and if the required cost targets and volumes can be met we also expect other HTS applications to become viable for the first time, including magnets for HEP.

To successfully make this transition from present “pilot” production lines to high-volume manufacturing one will need to scale to wider widths. We believe that the approaches typically employed for deposition of the initial amorphous buffer layers (e.g., Al_2O_3, Y_2O_3) and subsequent epitaxial layers (e.g., IBAD-MgO, $LaMnO_3$) in the HTS fabrication process can indeed be appropriately scaled, though they have only thus far been demonstrated at 12 mm width in production and at 5 cm widths in laboratory small samples. Though there are challenges, similar deposition methodologies (e.g., sputtering and electron-beam deposition) have already been demonstrated for roll-to-roll wide-web deposition in other industries. For deposition of the HTS layer, a number of possible approaches are still competing, and while it’s likely that no one approach will dominate in the near future, we believe that eventual deposition over areas greater than ~20 cm will be required for the cost reduction demanded by applications. Concerted engineering efforts are needed in both areas of scale up of: 1) template fabrication and 2) HTS deposition to make these cost reductions a reality. We believe that given such efforts cost can be brought down quite a bit from present costs.

References:

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[2] Matias, V. and Hammond, R.H. “Are $5/kA•m Coated Conductors possible?” Applied Superconductivity Conference Washington DC, Aug. 2010, presentation.

[3] Matias, V. and Hammond, R.H. “YBCO Superconductor Wire based on IBAD-Textured Templates and RCE of YBCO: Process Economics.” *Physics Procedia* 36 (2012): 1440-1444.